Winter Maintenance Practice in the Northern Periphery

ROADEX SUB PROJECT B PHASE I

EXTENDED SUMMARY AND CONCLUSIONS

PROJECT IS FUNDED BY ERDF,
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INDEX

PREFACE

The main goal of the Roadex project is to exchange information on experiences and practices on the maintenance of low traffic volume road network in the sparsely populated northern regions of Europe. The fields of the sub project B “Winter Maintenance” concentrated on winter maintenance of remote roads in harsh winter climates, and the need for information to the maintenance crew and the traffic users.

The Roadex Steering Committee nominated Professor Harald Norem at the Norwegian University of Science (NTNU) Trondheim, Norway to be the sub project B (SPB) work group chairman. The other nominated work group members, representing each partner district were:

Jukka Jääsko, Finnra, Lapland region, Finland

Lars Bergdahl, PRA, Northern region, Sweden

Arve Hegseth, PRA, Troms, Norway

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The information assembled is based on written answers of questionnaires for specific topics, interviews of supervisors, field trips in each partner district and literature review. The results of the project are presented in the State-of-the–art reports for both project A and B as well as a multimedia presentation on CD-ROM was made. Other publications concerning presentation of sub-project B and related issues are listed in the appendix at the end of this summary.

The present report is a concentrate of the main report issued and includes information on all topics treated by the project and the main conclusions. The report is written by Harald Norem and Skuli Thordarson.

Special thanks are expressed to all people involved in the project and for valuable comments during the process of making the report. Roadex Project Steering Committee and its chairman Tapani Pöyry have provided encouragement and valuable guidance for the work.

Trondheim, 04 September 2001

Harald Norem,
Chairman

1. INTRODUCTION

The road districts of Lapland in Finland, Norr Region in Sweden, Troms County in Norway, The Highland Council in Scotland and in Iceland have initiated a technical, international collaboration. The aim of this collaboration is, through the exchange of experience, to identify best practice strategies and to develop procedures in order to deal with common challenges associated with the maintenance of low traffic volume road networks in sparsely populated northern regions.The Roadex project is partly financed by the EU (ERDF, Article 10) funded Northern Periphery Programme, which is a co-operation between the northernmost regions of Finland, Scotland, Norway and Sweden.

The project was started in 1998 and is divided into two sub-projects: Sub-project A which deals with road condition management issues while sub-project B studies winter maintenance problems common to the co-operating partner road districts. The present report presents an extended summary of the results of the sub-project B on winter maintenance of roads.

The main goals of sub-project B are:

- The identification of the state-of-the-art maintenance techniques, traffic information systems, snow drift and friction control measures.
- The identification of best practice procedures for the various topographical and climatic conditions in order to improve accessibility and safety during difficult driving conditions

The workload in the sub-project has concentrated on the special problems posed by the Northern Periphery in the management and maintenance of roads in remote areas exposed to harsh winter climates. As a result the project has mainly focused on:

Road Design

- Cross-section profiles
- Use of guard-rails
- Use of snow fences
- Interaction between road design and winter maintenance techniques

Winter Maintenance

- Winter maintenance equipment
- Snow removal techniques
- Costs of winter maintenance

Operational Procedures

- Co-operation with the meteorological services
- Safety during severe driving conditions
- Authority to close the road during extreme weather situations
- Service standards for friction and snow removal

Information Systems

- Driving conditions
- Weather information

2. GEOGRAPHICAL AND CLIMATIC CONDITIONS

2.1 Characteristics of the climate in the Northern Periphery

The climate in the northern part of Europe is partly influenced by the polar front, which is formed where the tropical and polar air masses meet, and partly by the high-pressure systems in Siberia and the Azores. In the first case high winds and rapid changes in the temperatures often occur, and this kind of weather is usually found in west-facing coastal regions. In the opposite, when high pressures dominate in the winter there may be long periods with very low temperatures. The influence of the high-pressure zones is most distinct in the eastern parts of the studied area but they may sometimes cover the whole northern part of Scandinavia.

The Northern Periphery of Europe shows a dramatic diversity of climate conditions because it is in the transition zone between the north-western and central European climate zones. The types of climates found in the area vary from the arid continental climate in the central part of Scandinavia to the pure maritime climate in the coastal areas of the northern Atlantic region. The transition from one climate zone to another may be quite distinct and often follows the watershed.

The continental climate regions are characterised by cold winters, limited snowfalls and few days with wind speeds above gale (11 m/s). In extreme opposite to the continental climate is the mild maritime climate found in Scotland, the islands off northern Norway and close to the shore in Iceland. These areas are characterised by high precipitation rates and strong winds. The average mid-winter temperature is generally close to 0° C with the precipitation either falling as snow or rain.

The transition between these two climate systems is what we may call the “cold maritime” climate zone, which is mainly found in most of Iceland and along the coast and sea facing mountains of mainland northern Norway. These climatic areas are extremely windy compared to other areas within Europe and the main part of winter precipitation is snow. These features present the very worst conditions for keeping roads open for free traffic in the wintertime.

The annual precipitation within the Nordic countries is presented in Figure 1. The highest precipitation rates are mainly found along the western coast of Norway up to Troms County and on the southern coast of Iceland. The highest recorded annual precipitation in Troms is above 1500mm whilst Iceland can record as much as 3000mm in the southwestern mountains. As for the Nordic countries, also in Scotland is most of the precipitation found in the mountains facing to west, with a maximum of 3200mm.

The most arid areas in the Northern Periphery are found in central part of northern Finland and Sweden with an annual precipitation close to 350mm. The same low precipitation is also found in the north-eastern region of Iceland. The most arid areas of Scotland are also found in the north-east at approximately 600mm a year.

Of special interest to the Roadex project is the average precipitation over the winter season. This varies from 400mm to less than 50mm from the coast of Northern Norway to the border between Finland and Sweden. This variation is shown graphically in Figure 2, which details a transect along the 69 degree north latitude showing the altitude, winter precipitation and average January temperature. The figure clearly shows that the highest precipitation is found close to the coastal mountains. On the lee side of the watershed between Norway and Sweden/Finland there is a dramatic drop in the precipitation rates.

Another important parameter in analysing the magnitude and cost of winter maintenance of roads, is the number of days with snowfall. The highest numbers of days with snowfall is found in the coastal mountains in Norway, Iceland and Scotland with more than 70 days. The respective number in the dry continental areas in Finland and Sweden is less than 10 days in a winter.

The mean January temperatures varies from slightly or close to above 0° C along the coast of Scotland , Iceland and Norway down to –20° in central parts of northern Sweden and Lapland. The variation of the average temperatures in January from the coast of Norway to the Russian border is also presented graphically in Figure 2. This shows that there is a distinct fall in the temperatures both on the lee sides of the coastal mountains and of the mountain ridge to Sweden/Finland.

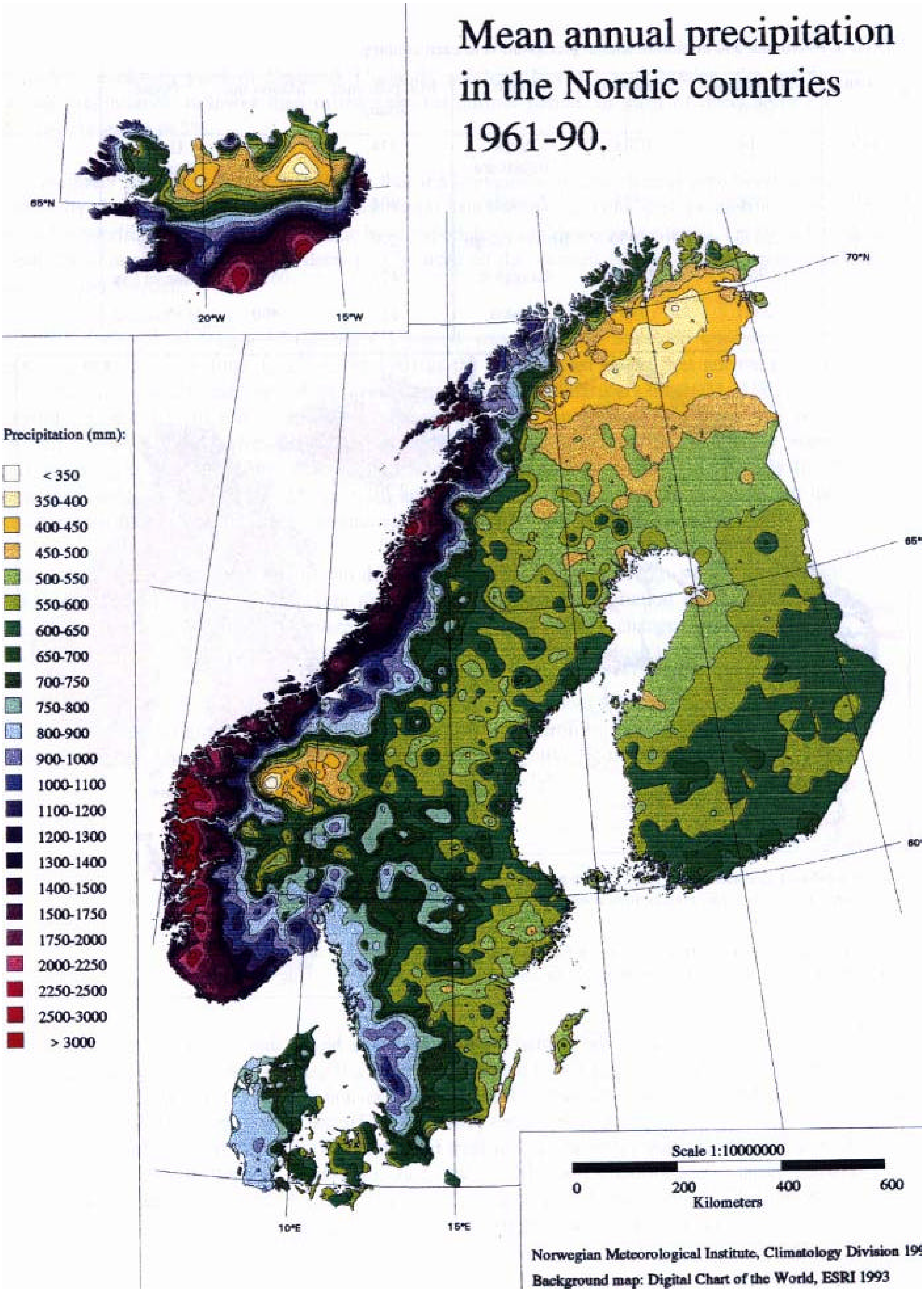

Figure 1. Annual precipitation in the Nordic countries. (Norwegian Meteorological Institude. Nordic precipitation maps, report no. 22/97 KLIMA)

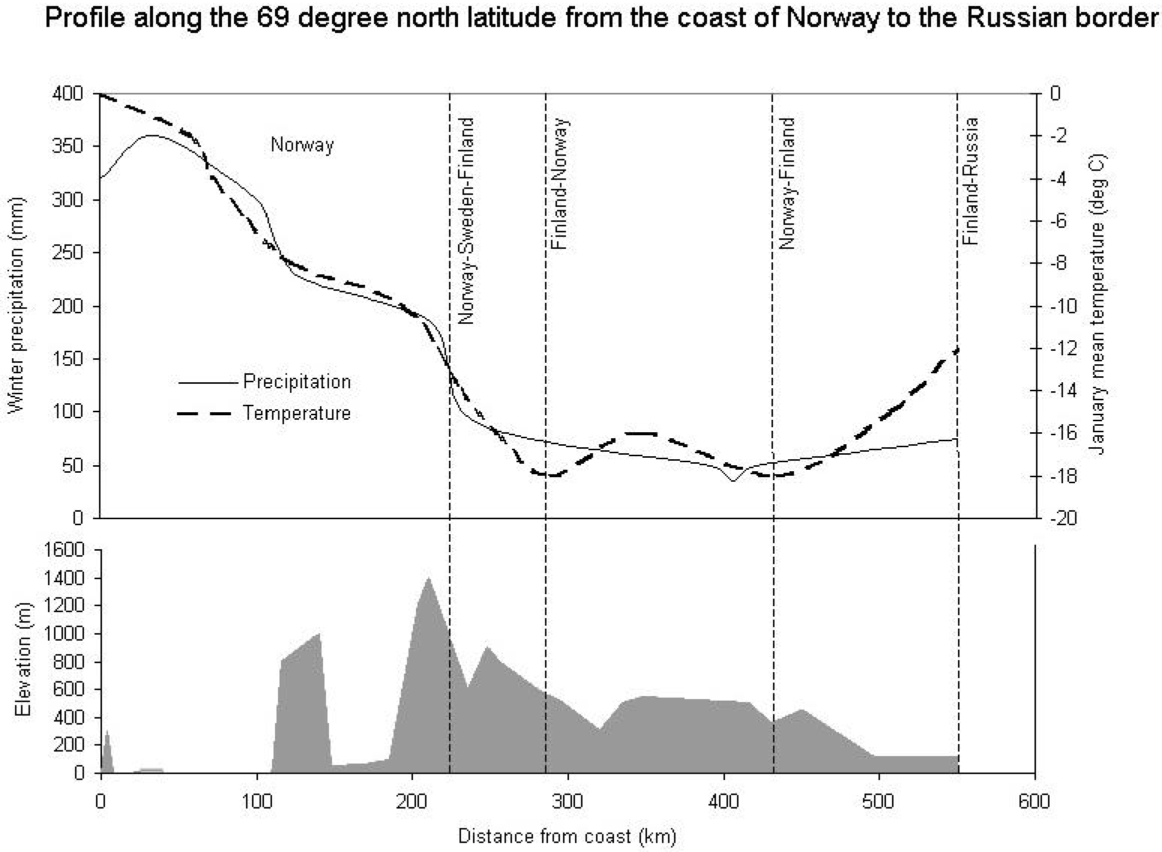

Figure 2. Profile along the 69 degree north latitude. Climatic variations.

The mean temperature in January in Scotland is above 0°C in those areas where there are public roads. Along the coast the mean temperature is 2-4° C, and close to 0° along some of the mountain passes. This shows that Scotland has the highest winter temperatures in the areas studied.

The wind speeds and the wind directions close to the surface are highly influenced by the local topographic features, like mountains, valleys, forests etc. Generally, both the average wind speeds and the frequency of gales and storm are highest in the coastal mountains, and drops substantially on the eastern side of mountain ridges.

2.2 Winter maintenance due to climatic and topographic features

The winter maintenance of roads is strongly influenced by climatic conditions and topography. In addition to these natural considerations road managers also need to take into account the general preparedness of traffic users to deal with difficult weather driving conditions when drawing up their winter plans. Investigations made for the present project show substantial differences across the districts on how drivers are prepared and equipped to meet winter conditions as well as their different expectations for the standards of winter maintenance.

Frequent night frosts and subsequent slippery roads in the morning characterise the mild maritime climates. The number of days with snow lying on roads is limited. As a result of this drivers are usually poorly equipped with winter tyres and are inexperienced in driving on slippery roads. Similarly in these areas roads authorities need not be geared up to meet the heavy snowfalls found in cold maritime climates.The need for friction control is thus higher in mild maritime climates than in areas where drivers are well equipped and have experience of driving on snowy and icy roads.

The continental climate areas represent the extreme opposite to the mild, maritime climates from the point of view of management of winter maintenance. Drivers are more prepared for the long winter conditions and the climate is usually cold and stable. During midwinter there are few variations of temperatures around 0° C, and there are few dramatic variations in the weather conditions from one day to another.

The main demand for winter maintenance in the continental areas is to keep the roads free of loose snow and to ensure that friction is within required standards. In these areas snow and ice may be acceptable on the roads. On windy days, however, snow may be eroded and transported by the wind. This drifting snow can reduce visibility for road users and may cause difficulties in keeping roads passable.

Cold maritime climates are characterised by long winters, frequent snowfalls and strong winds. The frequency of snow ploughing is therefore much higher in these areas and the heavy snowfalls make it necessary to use graders more often to remove hard packed snow and ice. The removal of snow from junctions, ditches and signposts to improve the sight distances is an operation not generally necessary in other districts. On roads severely exposed to snow drifts the roads may be temporally closed and convoy driving is introduced in some areas to get traffic through critical sections safely.

On major roads with high traffic speeds vortices at the rear of heavy vehicles often generate clouds of snow particles. Such kind of "snow smoke" causes reduced visibility and very difficult driving conditions for following and passing traffic, which has resulted in serious accidents during vehicle passes.

An increasing amount of inexperienced drivers are moving around the Northern Periphery as a result of modern mobility. These drivers seldom have experience of handling snow conditions and driving on slippery roads. Their cars are often badly equipped without winter tyres and they seldom carry chains. In all districts such inexperienced drivers have caused serious accidents and frequent road closures. In future the standards and the demands for winter maintenance of roads may have to be redefined to meet the accident risks caused by these inexperienced road users coming from the outside areas.

3. COST OF WINTER MAINTENANCE

3.1 Data for the different districts

The cost of the winter maintenance and the cost of the total winter maintenance within the different districts are presented in Table 1. The figures present an average of the years 1997-99, where the cost of the winter maintenance includes, removal of snow, friction control, winter marking and levelling of roads due to frost action:

For the total road maintenance costs given in Table 1, all maintenance costs are included, except, ferry costs, repavement, reconstruction and other kind of heavy investments.

The cost figures presented in Table 1 and graphically in Figure 3 indicate large variances in the cost of winter maintenance from district to district. These differences are likely to be the result of:

- Climatic conditions
- Topography
- Traffic volume and density of population
- Design and standard of the road network (note this includes expensive road elements like tunnels and bridges which can have high maintenance costs)
- Service standards for winter maintenance, mainly due to accepted levels of snow on the road and levels of friction
- Operation and safety procedures
- Organisation of winter maintenance

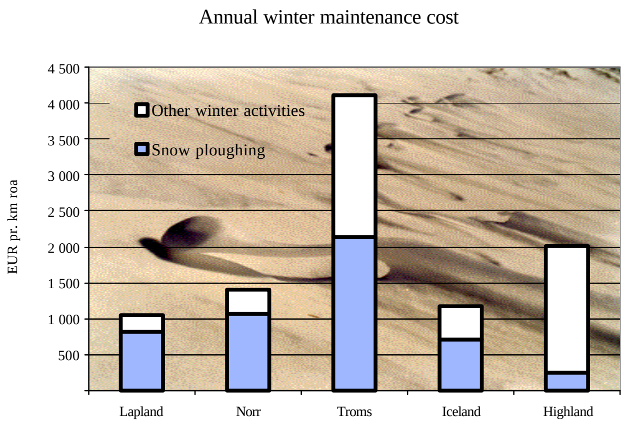

Figure 3. Average annual winter maintenance and snow ploughing costs divided by road network length for each partner district 1997-1999.

The least expensive winter maintenance per km road is found in Lapland, Finland, with Iceland and the Norr Region of Sweden as number two and three. Highland records expenditures approximately twice as high as Lapland and Troms County, Norway has winter maintenance costs four times higher than Lapland.

The relatively low costs for Lapland and Norr may be surprising, since these districts have the longest winters. However they also have a continental climate with few days with falling snow and few days with temperatures varying around 0°C. The standard of the roads is in addition generally high in both areas. Another factor that might influence their low costs is that the drivers in these districts are generally well prepared for driving on winter conditions, and as a consequence require lower service standards on secondary roads.

The winter maintenance costs per km in Iceland is comparable to Lapland and north Sweden, despite the very harsh climate found along all roads of Iceland. The reason for the low cost is primarily due to the lower service standard on the secondary roads,

Table 1. Road maintenance cost in the NP area.

		Districts				
		Lapland	Norr Sweden	Troms	Iceland	Highland
Total road network in NP	km	9 052	18 008	3 523	8 207	7 790
Roads subject to temporary closures	km		90	245	4 300	335
Total road maintenance cost	Million EUR	16.1	42.1	26.6	46.6	52.2
Total road maintenance cost / km	EUR / km	1 779	2 336	7 553	5 676	6 697
Winter maintenance cost	Million EUR	9.4	25.3	14.4	9.7	15.7
Winter / total costs		59%	45%	54%	21%	30%
Winter maintenance cost / km	EUR / km	1 041	1 406	4 104	1 177	2 009

where some roads may be closed, and some are only cleared of snow a certain number of days per month.

The Highland area records the second highest cost for winter maintenance. This result may also be surprising since Highland has 'less winter' than the other investigated districts. These high costs may be explained by the following factors:

- The majority of the Scottish road users do not change their tyres in winter. This results in a high demand for friction on all carriageways and the complete removal of snow even on secondary roads.
- Highland has a high frequency of days and nights with temperatures varying around 0°C.
- The number of days with falling snow is actually higher in Highland than in Lapland/north Sweden, 30-100 versus 10-20.
- The high service level is a consequence of the demands of the local economy. Fish products transported via the road network to Central Europe represent the major commercial product. The low durability of these products requires a high regularity of carriageway surface even on secondary roads.

Troms County has by far the highest cost of winter maintenance compared to any other districts. This may not be surprising when considering the climate and the topography, but the great differences need to be investigated. The main reasons for the high figures shown may be explained by the following factors:

- The number of days with falling snow is the highest of the investigated areas.
- The amount of snow on the ground is high, 1-2m in most areas. This requires an intensive removal of snow to improve the visibility in junctions, the removal of snow around traffic signs, and the clearing of snow from the ditches to create storing capacity for new snow.
- The frequency of days with temperatures varying around 0°C is relatively high.
- The service level is probably high, especially during difficult driving conditions with drifting snow and reduced visibility. In such situations convoy driving is offered regularly.
- The high service level is a consequence of the local economy. Fish products transported on road to Central Europe represent a major commercial product.

Table 2 Snow ploughing costs across the partner districts

		Districts				
		Lapland	Norr	Troms	Iceland	Highland
Total road network in NP	km	9 052	18 008	3 523	8 207	7 790
Ploughing	km	1 674 620	2 845 264	1 882 797		
Ploughing frequency	km/km	185	158	534		
Cost per ploughing km	EUR/km	4.4	6.7	4.0		
Snow ploughing cost	Million EUR	7.3	19.1	7.5	5.8	1.9
Snow ploughing cost / total km	EUR / km	806	1 059	2 135	704	241
Snow ploughing cost / winter cost		77%	80%	52%	60%	12%

3.2 Cost of snow removal

The differences in climate and topography across the Northern Periphery results in great differences in the cost for snow ploughing, Table 2.

The most expensive district, Troms, pays nine times more than the least expensive district, Highland, 2135 EUR/km versus 241 EUR/km. Between these two extremes is Iceland, Lapland and north Sweden, who pay from 704 to 1059 EUR/km respectively.

These differences are mainly a result of the length of the winter, total amount of snow, numbers of days with snowfall and effects of wind. To have a better understanding of the cost of the snow ploughing the parameter "Ploughing frequency" has been introduced. The parameter is defined as the number of passes on a road section of a snowplough per winter, and has the unit km/km. One ploughing back and fourth thus represents a ploughing frequency of 2. The numbers for the three northern Scandinavian districts is 534, 185 and 158 for Troms, Lapland and north Sweden respectively.

Even with the very high ploughing frequency for Troms, their cost of snow ploughing represents only 52% of the total winter maintenance, compared to 80 and 77% for north Sweden and Lapland. The cost of other winter activities like snow removal from junctions and ditches, organising convoy driving and friction control is clearly more expensive in the cold maritime climates with high snow depths and windy conditions.

In Highland the cost of snow ploughing is only 12% of the winter maintenance. This low figure is a result of snow seldom remaining on the road, despite Scotland having a fairly high number of days with falling snow.

3.3 Cost of friction control

All districts spread either sand or salt on the road to improve the friction on roads covered by ice or snow. The type of salt for all districts is ordinary rock-salt or sea-salt (NaCl). Salt may work effectively down to temperatures –6 to –8° C to prevent icing on the roads.

Scandinavian districts use sand to a greater extent than the other two districts. The magnitude of sand spread varies between 5.9 and 8.2 t/km in Northern Scandinavia and only 0.8 t/km in Iceland and 1.1 t/km in Highland, Figure 4.

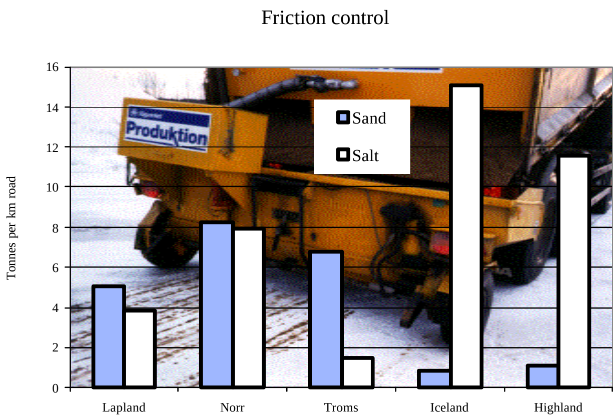

Figure 4. Average annual use of sand and salt for friction control in the respective districts 1997-1999.

There are substantial differences in the use of salt within the Northern Periphery. Highland uses salt on all public roads to avoid any ice forming on the carriageways, and partially to melt snow. The use of salt is thus very high, 90000 tons a year in Highland alone, which equals 11,6 t/km treated with salt. Iceland too makes extensive use of salt on the few roads treated by salt. In total only 4.3% of their roads are treated with salt, but the use of salt per kilometre is the highest among these districts, 15.1 t/km.

The northern districts of Scandinavia have less extensive use of salt. The Norr Region of Sweden treats only the major roads with salt. Only 3.5% of their roads are regularly salted each winter. The average use of salt is 7.9 t/km. This relatively low number reflects the high number of days with very low temperatures and few days with precipitation and high moisture. In Troms County in Norway and Lappland, Finland no roads are treated with salt regularly. Salt is used only on the major roads and only in the critical periods in the autumn and spring. The consumption of salt is thus very low, only 365 tons and 1000 t, which represent 1.5 t/km and 3.8 t/km respectively.

4. ROAD DESIGN

4.1 Road design due to drifting snow

An important task of the sub-project on winter maintenance was to identify any special procedures for the design of roads in drifting snow areas and on any interaction between the road design and the use of winter maintenance equipment. Included were comparisons on practices and experiences with the use of guardrails in snowy areas and the use of snow fences and tree planting to prevent snowdrifts on roads.

The requirements for a well-designed road exposed to snowdrifts are:

- Limited formation of snow on the road
- Limited transport of snow by the wind across the road
- Best possible visibility during snow storm conditions
- Reasonable construction costs
- Simple and cost-effective maintenance of the selected profile

Roads are recommended to be located in areas less exposed to strong winds, in areas with snow depths less than average, and, if possible, aligned parallel to the prevailing wind direction to achieve these requirements. Through this approach visibility should be improved and less snow accumulate on the road.

For optimum results in snow conditions roads should be designed with fills as high as the local snow depths and any cut sections should have gentle slopes and deep ditches. The slopes should have gradients of not greater than 1:6 in flat terrain where the slopes are found at the windward side of the roads. Roads may also be designed with steep cut slopes and with wide ditches for storing snow. Where roads are not well located or designed, conditions may be improved by redesign of the roads or by protection by snow fences or by tree planting.

These general recommendations are well known in all districts, but are, however, only expressed explicitly during the planning process for some specific roads.

The project revealed that special local solutions on the design of roads exist in Norway and Iceland. In Norway are roads subject to convoy driving during storm periods sometimes designed with an extended shoulder or special "blower lanes" on the outside of the road, Figure 5, where rotary blowers can operate to remove the snow side-cast by snow plough operations. These ”blower lanes” offer added snow storage capacity and can improve visibility during snowstorm periods. In addition these lanes make it possible to use the snow blowers in calm weather to prepare for the next snowfall.

Figure 5. Blower lane along a mountain pass in Norway.

In Iceland are sometimes special short distance winter-roads ”vetrarvegur” aligned to the side of the main roads, Figure 6. These winter-roads are used in places where the main road is subject to closure due to snow drifting problems and are located where snow seldom collects. The length of winter-roads vary in length from a few hundred meters up to one kilometer. In all cases they are gravel roads of low standard and are only used when the adjacent main road is closed by snow.

Figure 6. "Vetrarvegur", a special bypass along a difficult section.

4.2 Snow fences and tree sheltering

Snow fences have been used extensively in all northern regions over the last 50 years to influence snow drifting on roads. The use of these fences has been a natural development as the demand for mobility in winter conditions on the existing road networks increased.

The aim of snow fences is to deposit the snow from the wind before the snow-saturated wind reaches the road. To achieve this, fences have to be located at an optimum distance from the road to maximise their effect. Snow fences are sensitive to the topography adjacent to the road. In suitable areas snow fences collect a substantial quantity of snow and reduce the amount of snow reaching the road as well as increasing visibility for drivers.

The height of snow fences is dependent on the strength of the prevailing winds and local snow depths. In areas with modest snow depths and only a few snow-drifting events per winter, fence heights are usually 2-2,5 m. In more harsh climates, heights of up to 3,5-4,5m are commonly used, with 5,0m as a maximum. In most cases these fences have been made of wood, but other materials as aluminum, plastic and fabrics have been tested.

The last two decades the use of snow fences has reduced considerably. The main reasons probably being:

- Snow fences are costly to construct and not least, they require very expensive maintenance
- Developments in wider roads and ditches have made roads less vulnerable to snow deposits
- The development of more powerful snow removal equipment makes it easier to remove even thick snow deposits on roads.

Despite the use of snow fences has reduced every year, Iceland has recently developed a new type of snow fences made of recycled plastic, Figure 7.

Figure 7. Icelandic snow fence made of recycled plastic and standard signpost material.

In all Nordic countries, the tree line has risen for the last 50 years. The tree sheltering has made the roads less vulnerable for drifting snow and has in addition reduced the need for snow fences. Despite the very good sheltering effect of trees is well known, there are only recorded a very few experiments with tree planting along snow drift exposed roads.

A special technique on providing artificial shelter is reported from Sweden and Finland where a wall of snow is collected at a distance of 10-40 m from the road. The height of the wall is usually 1-2 m.

4.3 Use of guardrails

Although very useful for vehicle containment at dangerous locations, the use of roadside guardrails is generally a hindrance for cost-effective winter maintenance operations. The main disadvantages being:

- Guardrails can cause heavy snow deposits on the road during periods of snow drifting. These snow deposits can result in a need for increased frequencies of snow ploughing, and in very bad situations may even make the roads impassable.
- Guardrails tend to lift the height of the drifting snow and thus reduce visibility to drivers considerably in snowstorm periods.
- Guardrails can make it difficult to remove the snow from the shoulders of the road. One consequence of this is that melting water from snowbanks can flow onto the road and freeze during the nights. Several bad accidents have occurred due to such unexpected local slippery roads.
- Guardrails can be exposed to high vertical and horizontal forces in snowy areas. These forces can be caused by snow plough trucks during maintenance operations and by the weight of the snow in snowbanks forming around the guardrails. Guardrails generally therefore need greater maintenance in areas subject to snow and have a shorter durability there compared to areas with a milder climate.

The main type of guardrail in use in all districts is the W-type. This type is designed to take care for cars driving off the road and only minor consideration have been taken to the forces caused by snow and winter maintenance vehicles. As a result some northern regions have found it necessary to develop other types of guardrails to make a better compromise between safety and maintenance.

Table 3 List of main guard rail types used in the Northern Periphery and the experience there from.

Type	**Width** **Mm**	**Cost per meter EUR/m**	**Post distance m**	**Experiences**
W-type	230-320	38	2/4	Collects drifting snow Damage by snowploughs, graders and blowers. Ploughs scratching the surface of the rail Some damage due to the weight of snow. Maintenance costs: 2-3 EUR/year/m
Kohlswa	160		2/4	Collects less snow than the W-type No damage recorded due to weight of snow The type with 4m-post interval is more easily damaged during ploughing. No damage reported due to ploughing on the type with 2m post interval Easier to clear the road edges
Pipe-type	2x70	48	2/4	Collects little snow 4m-post interval is more easily damaged during ploughing. No damage reported due to ploughing on the type with 2m post interval
Wire			3,2	Collects little snow Can be easily damaged during ploughing
Open Box Beam	***			Only in use in Scotland with minor snow drifts.

The experience from the Nordic regions is that the W-profile show several weaknesses, mainly due to the collecting effect and the tendency to be destroyed by the weight of snow and by the acting side forces from the snow plough trucks.

The collecting effect of the guardrails is reported to be less for the more narrow types, Kohlswa and the Pipe-type (Figure 8). These types have in addition longer durability when the post-distance is reduced from 4 m to 2 m.

In any case will a guardrail be a hindrance for the winter maintenance of roads and should be avoided wherever possible. Where embankments are so high that guardrails are required alternative solutions like gentling out the slope of the embankment should be investigated.

Figure 8. Mainroad Vt 21 Kilpisjärvi 5.3.2000 Open area where drifting snow has caused problems with extra maintenance activities and costs. This has been reduced by using the ”pipe-type guard rail”.

5. WINTER MAINTENANCE

5.1 Maintenance equipment

Maintenance equipment dedicated to winter maintenance can be summarised as:

- Snow ploughs
- Rotary blowers
- Graders and underbody blades
- Sand and salt spreaders

The numbers of dedicated winter maintenance units divided by the road lengths are presented in the figures below, which indicate large differences across the districts for all types of equipment.

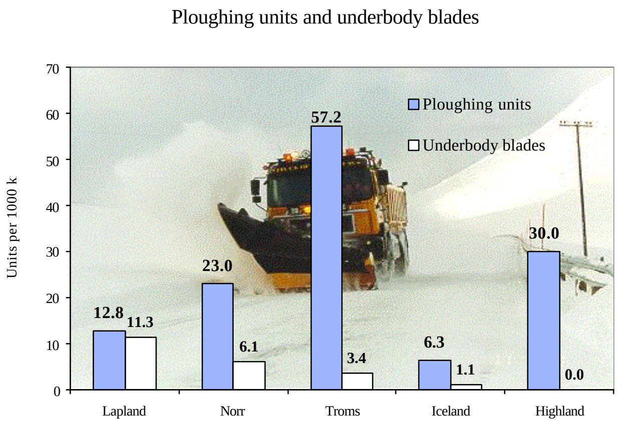

Figure 9. Snow ploughing units and underbody blades per 1000 km road across partner districts 1997-1999.

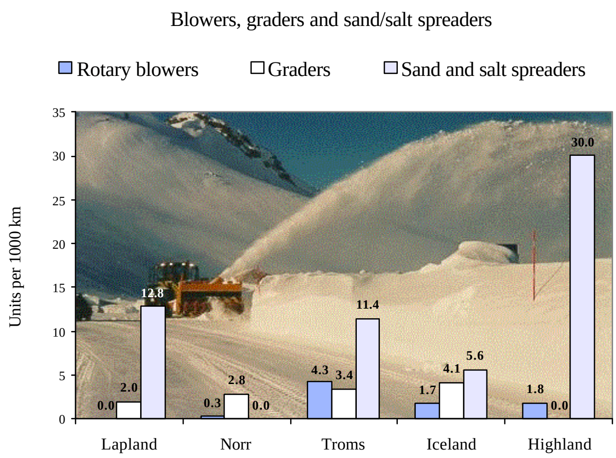

Figure 10. Rotary blowers, graders and sand/salt spreaders per 1000 km road across partner districts 1997-1999.

Snow ploughing units

The highest usage of snow ploughing units is found in Troms County at 57 units per 1000 km road, compared to 13 and 23 for Lapland and Norr respectively. These high number reflects the large amounts of snow in Troms County but may also be a result of lower road standard. A low standard of road demands lower vehicle speeds, and thus a longer time for one unit to clear a certain road length.

In recent years there has been an increase in the use of “underbody blades”, which are grader blades mounted under the mid-section of snow plough trucks, Figure 11. These blades work as a “light version” of graders and are usually less effective in removing and levelling hard snow and soft ice from the road surface than graders. The operation of the underbody blades is normally done simultaneously with snow removal, but may also be done together with spreading of sand and salt, or as a separate operation. In the first type of operation the speed of the snow plough truck has to be reduced when using the blade, but the use of dedicated graders is reduced. The introduction of “underbody blades” has for some districts resulted in summer maintenance needs being the critical factor in defining the numbers of graders, rather than previously, when the winter maintenance requirement was the critical factor.

Figure 11. Underbody blade on a plough truck.

The use of underbody blades is more developed in the eastern districts with continental climate than in the three maritime districts. There is no obvious reason for this, but it might be that underbody blades are more effective on roads with a high standard. The figures show that Lapland and Norr Sweden have equipped 88 % and 26 % of their snow removal trucks with underbody blades. The respective percentages for Iceland and Troms are 17 % and 6 %

The main type of snow ploughs in use is the conventional diagonal plough, Figure 9. The V-type plough is only used on some secondary roads, and in case of extremely heavy snowfalls, mainly on roads that might be temporary closed during the winters.

The only regions that report use of side-mounted ploughs are Lappland and Region Norr. This is probably due to generally wide roads and moderate amounts of snow on the snow banks. The side-mounted ploughs are used to remove snow from the shoulders and to remove snow banks.

Rotary blowers

The holdings of rotary blowers are mainly a result of the numbers of road sections exposed to strong winds and heavy snowfalls within each area. The highest numbers are thus found in Troms and Iceland. The most powerful rotary blowers are also in use in these districts. Rotary blowers are not used in Lapland.

The most used type is “Unit fan-blowers”, which are aggregates consisting of a fan and a motor made as a unit and carried by a loader, Figure 10. The capacity varies between 200 and 600 m3/hrs.

Graders

Graders are used for both summer and winter maintenance. The winter purposes are mainly snow clearance, reducing unevenness, reducing the height of snow walls and removing snow from ditches. The highest numbers of graders are found in Iceland and Troms, with 4.1 and 3.4 per 1000 km road respectively. Probably the numbers of graders in these areas is governed by the local winter maintenance need, rather than in north Sweden and Lapland, which have a high ratio of gravel roads in their secondary roads.

Graders are not reported to be used for winter maintenance purposes in Scotland.

5.2 Snow removal techniques

There are substantial differences in techniques for snow removal across the Partner Districts, especially on the removal of snow from road shoulders and ditches. These differences go back mainly to differences in climate and road standards.

Snow banks on road shoulders cause problems for traffic during the winter by:

- Reducing available sight distances in curves and at intersections
- Decreasing visibility during periods of drifting snow across the road
- Limiting space for snow storage
- Increasing the hazard due to wild-life crossing the road
- Thawing snow banks in spring can cause water flows across the road which can then freeze during the nights
- Damming of water in depressions on the roads

On the other hand there is a benefit to have snow cover in roadside ditches as this can prevent water flowing on to the road and forming ice, Figure 12.

Figure 12. Ice building up in ditches. The ditch is full of ice, the water flows onto the road creating slush and ice, with a traffic danger point as result

All districts, except Highland, report that removing or lowering roadside snow-banks is necessary. The maximum height of the snow banks to assure the sight distance is 0,9 m according to Swedish standards. The required sight distance in road crossings varies between 80 and 190 m depending on the traffic speed. In addition to the benefits of reducing the height of the snow banks described above, the process also improves the thaw characteristics of the embankment and this in turn permits the road construction layers to dry out faster. In the spring it is especially important to remove the snow banks to prevent melting snow draining onto the roadway, causing localised wet and icy stretches.

The most common technique to remove snow banks is by trucks with side wings, graders with side wings, although loaders with a blade may also be used. Troms reports of a special procedure for removing snow from ditches and cut sections. A grader with a side wing takes the snow from the ditch on to the road and a following rotary blower then throw the snow far away from the ditches.

Figure 13. The procedure of taking down high snow banks to make room for new snowfalls. In front, a grader tears down the snow bank with a snow wing, and behind a blower is clearing the road.

To prevent the icing problem in ditches it can be effective to divert ditches away from the road and heating cables are sometimes installed in sub-drains. Double sub-drains have also been tried, with one overflow sub-drain placed above the normal drain. When the lower drain is clogged by ice, the overflow sub-drain takes care of the water until the normal sub-drain is opened. Excavators are often used to remove ice from the ditches. Steam cleaning is also used to open frozen sub-drains.

Icing on steep rock cuts may lead to traffic hazards when the interface between the rock cut and heavy ice blocks starts to melt and the ice blocks slide down onto the road. Fortunately, this is only a problem where ditches are very narrow, Figure 14.

Figure 14. Ice formation in a rock cut. In the spring thaw the ice may fall down on the road.

To prevent this type of hazardous ice building up on rock cuttings surface water can be diverted by ditches on the top of the cut. The rock face may also be equipped with netting to prevent ice from falling down on the road during the spring thaw. Removal of dangerous ice with excavators or other machines in the spring is also carried out.

6. OPERATIONAL PROCEDURES

6.1 Safety procedures

The climatic conditions in the Northern Periphery can cause very difficult and hazardous driving conditions. Sometimes these conditions reach such critical levels that roads should not be left open to free traffic. The most common actions implemented by Roads Authorities during severe driving conditions include; road closures, convoy driving, reduced allowable speeds and surveillance of the traffic.

Some of these actions reduce free access to the road network and they are only implemented after thorough considerations. The main questions to be addressed in such situations are:

- What are the limiting conditions before special precautions need to be introduced to take care of the safety of road users and maintenance crews?
- What are the most appropriate actions?
- Who has the responsibility to enforce the appropriate actions?

The present study showed that there are great variations across the participating districts concerning these three questions. The differences may be explained in part by the differences in climates and road standards, but they are also reflected by different views on maintenance policies and safety. The harmonization of these issues would be advantageous to long distance and international traffic.

Service standards for friction and maximum snow depths on carriageway surfaces need to be defined to ensure that roads are both trafficable and safe. This is especially important for long-distance vehicles that pass through several maintenance districts to ensure that they meet consistent standards along their journey.

Winter speed limits

Reduced winter speed limits are used on some roads in Finland and Sweden. The winter speed limit in Finland is lowered from 100km/hr to 80km/hr on high traffic volume roads but is not generally enforced on low traffic volume roads. In Sweden the speed limits are for some roads lowered from 110km/hr to 90km/hr or from 90km/hr to 70km/hr in the winter. These speed restrictions are normally made on longer road sections with high traffic volumes.

Roads with temporary closures

Both Region Norr and Troms report that convoy driving is introduced on sections of mountain roads that may have temporary closures. Convoy driving is introduced whenever the visibility is reduced or when there is high risk of cars getting stuck in the snow. Road closures and convoy driving are enforced by locked gates and information on closures is given by means of signs about possible diversionary routes and where to get further information, Figure 15.

Convoy driving is carried out with a snow plough truck to lead the convoy and a pickup truck that drives at the rear, ending the convoy. A suitable private vehicle can also be used as the last car. The lead snow plough and the last vehicle have radio connection. The maximum number of cars in a convoy depends on the weather conditions, but usually no more than 10 or 20 vehicles are allowed in one convoy.

Before the convoy starts the lead snow plough truck driver inspects the participating cars and drivers to decide if they are adequately equipped. The driver has the authority to reject whoever he considers unsuitable to take part in the convoy, for instance if the vehicle's tires are not good enough, or if the driver or passengers are not fitted out with warm clothes etc.

A leaflet containing the general instructions for convoy driving is distributed to the drivers before passing along the affected route.

Figure 15. Sign on road E10 just out side Kiruna with a fixed message; "Snow obstacle, road E10 closed Björkliden-Riksgränsen, for information call 020-227766".

Authority to close roads

The authority to close roads varies among the Partner districts. All Scandinavian regions have the responsibility to enforce road closures when the driving conditions are to poor and the probability for accidents are assumed to be too high. The highway authorities also have the responsibility to introduce convoy driving when the visibility is too bad for free traffic.

In Iceland only the Police has the authority to force road closures. The road authorities can only state that a road is non-passable. In recent years it has become very popular to drive powerful 4x4 on big tires in winter. These cars have caused problems with non-passable roads because of their ability to drive on snow in very bad conditions, and because the roads are not closed by gates.

Only the Police have the responsibility to close roads in Scotland, but this decision is usually taken after consultation with the Roads Authority, who carries out the winter maintenance operation. Once the decision to close the road is made, road closed signs are erected. In some cases the Police will man the site of the closure to ensure that motorists do not attempt to use the road.

6.2 Winter marking

Winter marking is used as an optical guide for winter maintenance crews and road users. The winter marking may either be combined with the permanent marking or by separate temporary poles and signs.

The temporary markers are usually plastic sticks equipped with reflection stickers or painting. The use of reflection stickers is especially important in the Northern regions with the very long winter nights, Figure 16. On low-traffic roads sticks of bamboo and birch are occasionally used. A combination of temporary and permanent poles is the extensible poles frequently used in Iceland.

Figure 16. The effect of reflector tape on temporary poles at night.

The temporary poles are placed with a distance of 50-90 m, with the shorter distance in curves. The Swedish practice requires the reflex to be visible from a distance of 120 m when using half-lights. Longer temporary road markers are used on roads with snow drifting problems and the pole to pole distance is then decreased to 20-50 m, with 10 m as a minimum. Ends of guardrails and other hazardous points are usually marked with double sets of poles.

The distance of the pole from the edge of the road varies with the alignment and width of the road. Normally the poles are placed 5-25 cm outside the pavement edge, Figure 17.

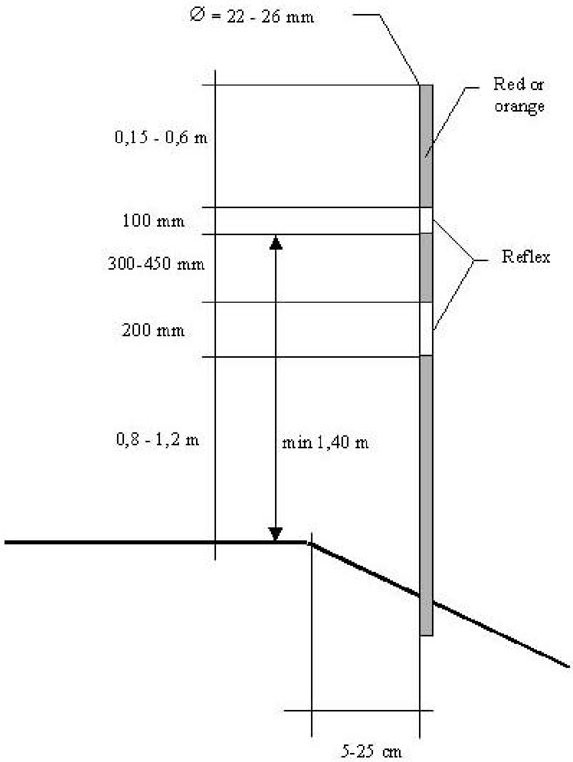

Figure 17. A sketch of a temporary snow pole, dimensions and placement

Sweden has carried out tests with fluorescent temporary markers. These markers were found to produce a big improvement in visibility for snow plough drivers. Fluorescent markers cost about 3 times more than ordinary road makers. Another test is to study the interaction with lorry headlights with UV-light to further improve the visibility. The results so far are good and the tests will continue.

Fixed poles, with no additional winter marking, are usually used on major roads and in areas with moderate amounts of snow. In Scotland some of the mountain road sections have elongated fixed poles to combine the requirements for both summer and the winter marking.

6.3 Service standards for friction and ploughing

The most common climatic effects that cause difficult driving conditions in the winter are snowfalls on the road surface and slippery roads due to snow and ice. All districts, except Highland, which has a “black road” policy, have defined critical levels for maximum snow depths and minimum friction. These levels are defined by national standards for winter maintenance. These standards also include permissible depths of ice on roads, times to improve sight distances at junctions, clear traffic signs etc.

The critical levels for snow depths and friction are either dependent on (a) the traffic volumes and the importance of roads or (b) the traffic volume alone. National standards set requirements for an acceptable level for snow and friction together with a reaction time to improve the conditions to this level. As a consequence of this it is difficult to easily compare the different standards across the partner districts, as there are both critical levels and reaction times involved.

Figure 18 summarizes the maximum snow accepted and the reaction time for the highest maintenance class for the four Nordic regions and it indicates that there are some similarities between the countries. The vertical axis on the figure shows the allowed snow depth and the horizontal axis the reaction time. Troms requires that the maximum snow depth on the carriageway is 7 cm, while Region Norr allows only 2 cm, but with a reaction time of 4 hours. By assuming that a heavy snowfall has an intensity of 1 cm/hour, the service standards are very similar for all four regions.

The corresponding winter standards for friction similarly differ across road districts and it is not possible to present the various requirements in a simple graph. On friction control, a comparison indicates that Lapland has wider requirements for friction as a function of traffic volume compared to the other Nordic districts. On the other hand, the Norr Region has no specific requirements for their secondary roads with very little traffic.

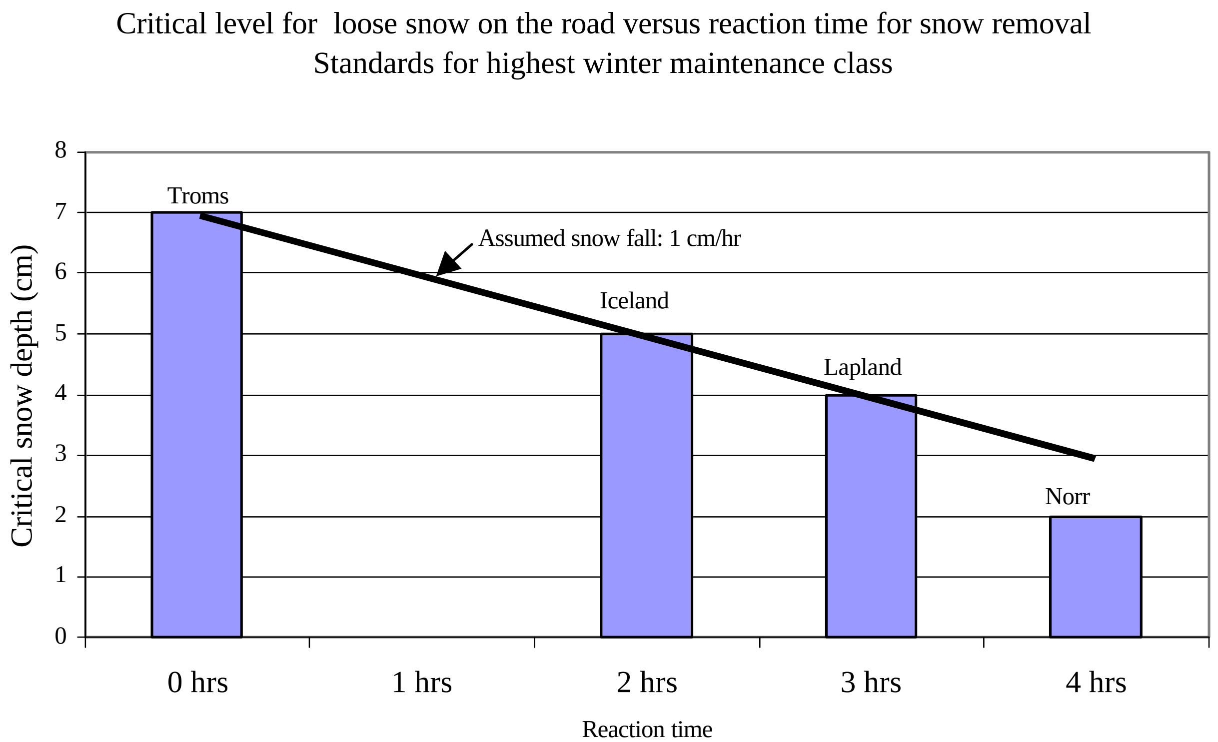

Figure 18. Critical level for loose snow on the road versus reaction time for snow removal. Standards for the Nordic districts and highest winter maintenance class

7. INFORMATION SYSTEMS

Cost-effective operation and winter maintenance of roads is dependent on reliable systems for the assembly and distribution of information on weather and driving conditions on the road network. The purpose of this is:

- To assemble information for the operation of the roads.
- To distribute appropriate information to the road-users.

Assembling information

The operation of roads in winter requires reliable data on actual conditions at critical road sections and access to the very best weather forecasts. The Public Roads Authority thus needs to be able to assemble information from people on the road, from instrumented road stations and with the good co-operation of the meteorological services. The latter is extremely important, as the interpretation of modern weather forecasts need to be done by experienced professionals to give accurate forecasts. This information is assembled through:

- Instrumented stations transmitting data of actual weather and road surface conditions
- Co-operation with the weather service
- Weather radars
- Operation of TV-cameras at critical road sections
- Information from the road-users
- Patrolling by the maintenance crew

All districts records to have developed an extensive net of weather stations, assembling data of the weather and road conditions. Some stations are in addition equipped with road weather cameras. The data is monitored at the Traffic Information Centres (TIC's) and distributed to all maintenance centres run by the PRA. Lappland, Region Norr and Iceland distribute in addition most if data from the weather stations on their web-sites.

All districts report to have a very close co-operation with their national Weather Bureau. The PRA both assemble climatic data for the weather service and receives in return detailed weather forecasts and forecasts for icing conditions on the roads.

Distribution of information to the road-users

At all times there is a need for the roads-users to be informed about the driving conditions. This need is especially high during severe driving conditions when road-users need to be aware of any major deviations from the normal conditions so that they can select the best route and be able to ascertain the expected time for their trip.

This information is generally expressed in 2 forms: (a) that which the road-users need to have to make their journey and (b) other useful information. In the first group are road closures, expected closures, convoy driving and other kinds of extreme driving conditions. The latter group includes road surface conditions (ice, snow, bare), weather conditions and any other hindrances to free traffic. A primary task for the roads authority is to select the kind of information that should go into each of these groups.

National or regional Traffic Information Centers (TIC) organise the distribution of information in all partner districts. They have a close contacts with the police, the regional emergency centers and the weather service, and they distribute their information by using:

- Traffic signs, temporary or variable
- TV and radio
- Telephones via Traffic Information Centers
- Internet

To further describe the tasks of the traffic Information Centers Figure 19 presents a graphical description of the assembly and distribution of information for the Traffic Information Center in Rovaniemi, Lappland.

Road-users are in addition usually given information on winter maintenance policy and advice how to behave in case of difficult driving conditions by specially designed leaflets.

The recent years there has been a rapid increase in the use of variable signs to inform the public on the roads. The signs give information on difficult driving conditions, convoy driving and alternative routes. Iceland is so far the only country to have variable signs to inform about the weather conditions at critical road sections, Figure 20.

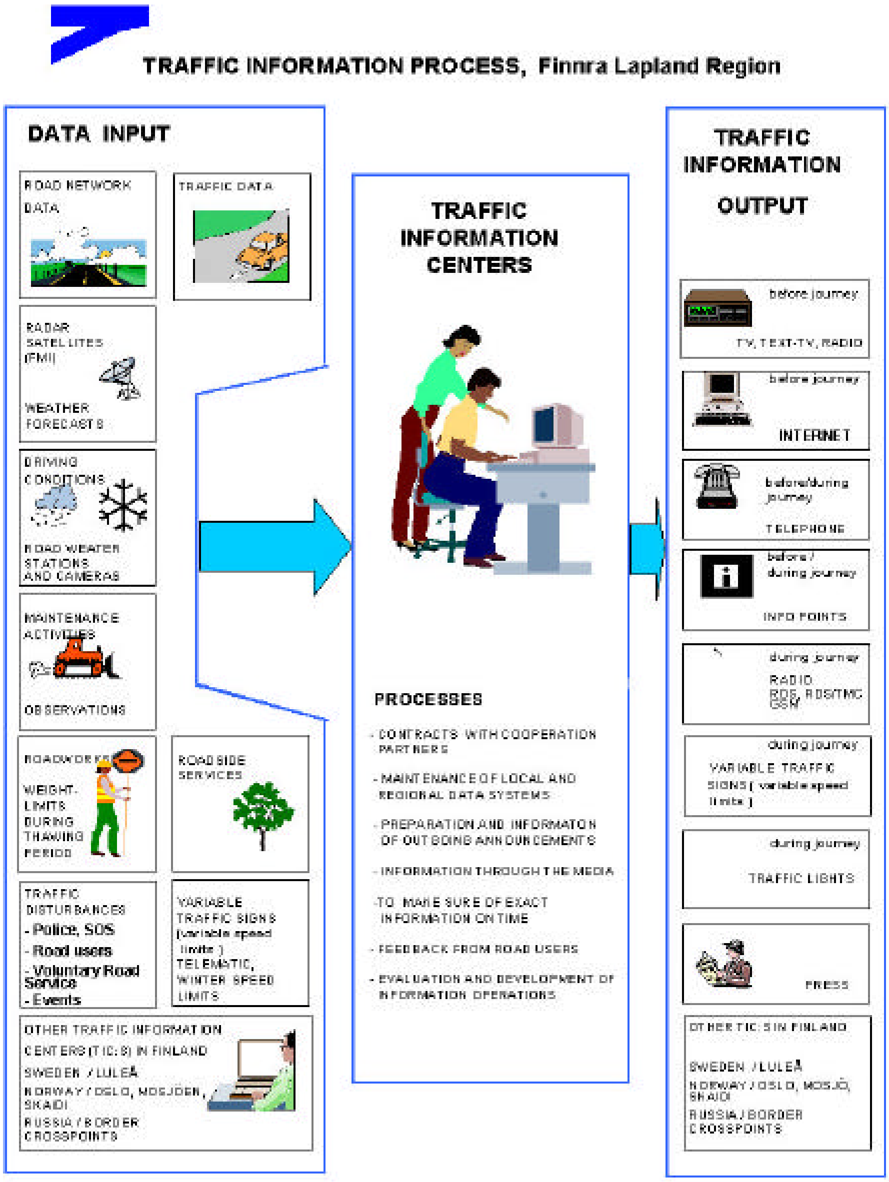

Figure 19. Traffic information process.

Figure 20. Variable signpost monitoring weather station.

APPENDIX,
ROADEX PUBLICATIONS

Following are references to presentations and publications from Roadex Subproject B, Winter maintenance.

1. Tapani Pöyry, presentation at the Winter Road Congress in Tampere, 2.-3.February 2000.
2. Tapani Pöyry, Technical Exchange in the European Northern Periphery to Identify Best Practices in Winter Maintenance. PIARC Winter Road Congress, 2002, Sapporo.
3. Norem, Thordarson. Operation of roads exposed to drifting snow in Northern Europe. Proceedings of the 4th International Conference on Snow Engineering, Trondheim 2000.
4. Norem, Saetran,Thordarson. Measures to reduce the generation of "Snow Smoke" behind heavy vehicles. PIARC Winter Road Congress, 2002, Sapporo.
5. Thordarson, Norem. Design criteria for roads in snow-drifting areas. PIARC Winter Road Congress, 2002, Sapporo.
6. A PhD. student at NTNU, Skuli Thordarson, has been partly financed by the Roedex project. His thesis on road enginneering in snow drifting areas is scheduled for defence in 2002. The method of the project is to use numerical simulations to find better criteria for the design of roads exposed to snowdrifts. By june 2001 the following material from the research is available:
    - Thordarson, Norem. Simulation of two-dimensional wind flow and snow drifting applications for roads, Part I & II. Proceedings of the 4th International Conference on Snow Engineering, Trondheim 2000.
    - Thordarson, 2000. Guard drails, evaluation of snow drifting properties by wind flow simulation. Internal note to the Icelandic Public Roads Administartion.
    - Thordarson, 2001. Road cuts, snow drifting evaluation. Internal note to the Icelandic Public Roads Administartion.
    - Thordarson, 2000. Climatic analysis for mountain road Kaperdalen. Internal report to the Troms county PRA.
    - Thordarson, 2000. Troms Suggested modification of the Kaperdalen Road. Internal report to the Troms county PRA.
    - Thordarson, 2001. Wind tunnel experiments and numerical simulation of snow drifting around avalanche dams. To be submitted to Environmental Fluid Mechanics, Kluwer Academic Publishers.